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ARMSTRONG LABORATORY

IMPACT OF NEW TECHNOLOGIES ON MANUFACTURING ENVIRONMENTS

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13. ABSTRACT *(Maximum 200 words)*

The present work contributes an understanding of the human and organizational factors that are important for the successful implementation of new technology by an organization. Results include a template of success factors, with which an organization can assess its readiness to undertake new technology, and a technology implementation methodology tailored to the organization's state of readiness. The implementation methodology, which follows a continuous-improvement process, balances the needs of the organization with those of its people and the characteristics of the new technology. The content validity of the technology implementation methodology was developed from fifteen case studies in the literature and performing team's experiences. Two additional technology transfer cases at the San Antonio Air Logistics Center were then studied, and it was found that the methodology correctly discriminated between the relative success of the cases.

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Table of Contents

List of Figures

List of Tables

PREFACE

The work described in this final report supports the Armstrong Laboratory Logistics Research Division's (AL/HRG) mission to improve the Air Force's ability to acquire and maintain the most effective systems at the best price. Recognizing the importance of new technology to this mission, AL/HRG created the program "Human Issues in Technology Implementation (HITI) " to account for the key roles that human and organizational factors play in the successful implementation of new technology. The present effort, sponsored by HITI, has produced an understanding of these factors and has developed a methodology for effectively dealing with them in manufacturing environments.

This report is offered in satisfaction of CDRL Sequence A058 in the Technical Requirement outlined in Paragraph 3.5 of the Task Description/Specification for Delivery Order 5014 under Contract F42650-92-D-0012 "Impact of New Technologies on Manufacturing Environments (Part II)." The performing project team consisted of members from the Concurrent Engineering Research Center (CERC) and the Center for Entrepreneurial Studies and Development (CESD), which are both affiliated with West Virginia University. CERC personnel included Drs. Ralph T. Wood (principal investigator), Michael E. Fotta, and Harshvardhan Karandikar; CESD personnel included Dr. Jack Byrd, Jr. (principal investigator), Dr. Julie Smith, and Mr. Charles J. Fleischer. Our team gratefully acknowledges the guidance of the contract monitor, Captain Robert Smith; the watchful oversight of Mr. Garth Cooke representing the prime contractor, NCI Information Systems; and the help of our support staffs.

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IMPACT OF NEW TECHNOLOGIES ON MANUFACTURING ENVIRONMENTS

SUMMARY

This final technical report summarizes the results of an investigation into how to identify and overcome the critical organizational, cultural, behavioral, and other barriers that inhibit success in the implementation of new technologies in manufacturing environments.

The investigation began with the observation that technology transition is a change process that affects all components of an enterprise—its people, its technology, and its business. This observation led to the working hypothesis that the successful assimilation of a new technology requires harmony between the new technology and the components of the enterprise. From this hypothesis flowed the identification of a set of success factors for enterprise harmony and the development of a template with which an organization can assess its readiness to take on new technology. Fifteen case studies taken from the literature and from personal experiences, including two cases studied as part of the present endeavor, were used to validate the completeness of the readiness template.

Next, turning on the readiness of the organization and its improvement priorities, a methodology or "road map" for successful technology transition was synthesized. The road map defines a technology implementation strategy that balances the needs of the business with those of its people and the characteristics of the new technology. Finally, by applying the road map as part of a tested change-management strategy, a plan for how to adopt this technology-transfer methodology at Air Logistics Centers and other agencies was developed.

The technology-transfer road map was applied (after the fact) to two technology transfer cases at the San Antonio Air Logistics Center. The road map did discriminate correctly between the relative successes of the two cases; although, more work will be required to establish the predictive validity of the methodology. For this purpose the methodology should be applied to new technology implementation projects from the start.

INTRODUCTION

Background

A major objective of the Armstrong Laboratory Logistics Research Division (AL/HRG) is to improve the Air Force's ability to acquire and maintain the most effective systems at the best price. Current efforts have focused on technology solutions and the support of technology developments in the areas of information management, concurrent engineering, and integrated manufacturing. These areas represent initiatives in the Air Force Computer Aided Acquisition and Logistics Support (CALS) and Integrated Weapon System Management (IWSM) programs. As the innovation process moves from the development to the application and implementation of these technologies, there is an increasing focus on the human and organizational factors that must be taken into account if the technologies are to realize their potential in useful practice. Recognition of the importance of these factors led to the creation of the Armstrong Laboratory Logistics Research Division Acquisition Logistics Branch (AL/HRGA) program "Human Issues in Technology Implementation (HITI)," which sponsored the present investigation.

The concerns underlying the HITI program are well founded, for there is ample evidence to demonstrate that the adoption of new technology by an organization is often fraught with disappointment. These concerns are as follows:

- promised benefits are not realized after a major investment;
- old problems remain; and
- productivity, instead of increasing, may be negatively affected.

A typical case in point is the unfulfilled promise of Computer Aided Design (CAD) systems, which a recent study (Liker, et al., 1992) disclosed are "radically underutilized." The study blamed companies for not matching the capabilities of CAD technology with the organizational structure and nature of the tasks in question. In some cases CAD technology had been "oversold;" in most cases the organization and related culture did not permit the degree of cooperation required for effective use of the technology nor were the competitive advantages of the technology understood; and in other cases CAD was not an appropriate solution for the task at hand. In short, because of organizational and cultural issues, few were using the technology according to its intent.

The starting point for the present program was the question, "Is there a 'formula' for the successful assimilation of new technology by an organization?" To find the answer to this question, AL/HRGA tasked the program of investigation with the objectives described below.

Objectives

There are three objectives for this program, which has the immediate mission of assuring the successful transition of new technology into the manufacturing operations of Air Logistics Centers. The objectives are as follows:

1. identify and analyze critical factors for integrating new technologies into manufacturing organizations;

2. synthesize an implementation methodology for successful technology transition; and

3. develop a plan for the adoption of this implementation methodology by Air Logistics Centers and other Department of Defense agencies.

Following is a brief overview of the technical approach taken to fulfill these objectives.

Overview of Approach

The research team adopted the working hypothesis that the successful assimilation of new technology by an enterprise requires harmony among the elements of the enterprise—its people, its technology, and its business. In consequence of this hypothesis, the critical factors sought in Objective 1 (above) derive from the effects that a new technology has on enterprise harmony. These factors were educed by studying the inverse (negative) case to identify and understand the barriers to harmony. Once identified from multiple sources, the factors were then formulated into a readiness assessment template, which measures the organization's potential for achieving success with the new technology.

Next, to fulfill Objective 2, a technology transition methodology was synthesized from the elements of several change-management strategies. The resultant methodology, called the road map, helps an organization identify its readiness weaknesses with respect to a specific new technology and the cultural and business environments of the organization. The road map also helps the organization define and prioritize remedial actions to improve its readiness while introducing the new technology.
Finally, in satisfaction of Objective 3, the use of the road map itself was demonstrated in defining a plan for adopting the technology implementation methodology that the road map represents.

The road map was constructed using the Quality Function Deployment (QFD) tool, which offers the versatility and features needed for the present purpose, including a mechanism for integrating the many perspectives of the organization and linking together the activities associated with milestones in the road map.

Related Work

The present approach was initially established from the experiences of the project team, whose members represent a diversity of backgrounds, affiliations, and cultures. Team disciplines include engineering, manufacturing, behavioral psychology, and cognitive psychology. Team backgrounds include academia, industrial research and development, and industrial production. Team experiences include hands-on technology design and implementation of hardware, software, and information systems in both new products and new processes; the measurement, improvement, and maintenance of production systems; and many professional engagements involving organizational improvement and change management. Once the basic approach was developed, validation and improvements were sought in the literature and in a real case study with an Air Logistics Center.

A primary contribution to current knowledge about technology innovation is the work of Tornatzky and Fleischer and their colleagues at the Industrial Technology Institute. These authors (1990) defined the life cycle of the technology innovation process, including creation, development, deployment, adoption, and implementation, then distilled a wealth of evidence to support recommended activities that should occur during each of these stages. In terms of the distinctions made by these authors, the present approach is user focused, and it advocates a holistic, system design perspective to technology adoption and implementation. In effect, the present approach provides a rational methodology for realizing many of the generic activities advanced by Tornatzky and Fleischer as necessary for successful technology adoption and implementation.

The central notion of enterprise harmony and its consequences has ties to the work of several investigators. Tornatzky and Fleischer advocate the system design perspective that seeks to maximize the benefit of a technology innovation to the organization, while jointly optimizing the organization's social and technological systems.

Majchrzak (1991), in a methodology labeled Highly Integrated Technology Organization and People (HITOP), identifies three keys to the success of advanced manufacturing technology: congruence among critical elements of the organization; congruence among the elements of the to-be human infrastructure; and the use of a staged analysis process. This analysis process examines readiness issues involving organizational commitment, critical features and relevance of the technology, roles and responsibilities for operations and support functions, skills and training, and organizational design.

Stokes (1991) offers a model for understanding change in which three systems—social, technical, and administrative—operate continuously and simultaneously inside the organizational environment. Within these three systems are identified four cornerstones fundamental to all organizations: jobs and tasks to be accomplished; people to do them; tools that they use; and working arrangements within which the tasks, people, and tools are organized. "Tools" in this context include "hard" tools, such as machines, equipment, computers, and "soft" tools, such as knowledge, skills, competencies, attitudes, and values. Stokes observes that change in one of the systems or cornerstones will affect all the other systems, and that “having the forethought . . . to anticipate the impact of change in one set of 'systems' upon the others will go far toward enabling organizations to manage change with a minimum of disruption and animosity.”

In a less comprehensive but no less credible undertaking than that of Tornatzky and Fleischer, Fowler and Maher (1992) developed a focused approach for the technology transition of software. This work views an organization as five subsystems: strategic, technological, structural, human/cultural, and managerial. The managerial subsystem is held responsible for maintaining the other systems in balance and for promoting their efficient and effective interaction to accomplish the organization's mission. The authors conclude in their section about the context for transition: “Because all technical organizations conduct both technological and non-technological activities, attention to only the technological aspects of a technology transition effort will result in a less than optimal level of success at best.” Fowler and Maher also advance a process chart of transition activities.

Finally, the work of Kaplan and Norton (1992) identifies a balanced approach to measuring and managing the several perspectives that are important to a business: customer satisfaction, value of internal processes, innovation and learning, and shareholder satisfaction. In the present context, Kaplan and Norton provide a framework for measuring enterprise harmony.

In the preceding expositions, the meanings and usages of the terms “balance,” “congruency,” “holistic,” “integrated,” “ disruption,” “animosity,” and “systems perspective” support the concept of enterprise harmony. Although there appear to be several open research issues in the field of technology innovation, enough is known about the key steps to success that an organization can profitably apply this knowledge to specific cases. The present approach, synthesized from several before it and from extensive personal experiences, strives to provide an accessible, tailored methodology for technology adoption and implementation that incorporates this knowledge while guiding the organization to harmony among its critical elements. To support the need for rational decision making and planning in this process, the resulting methodology and process “road map” emphasize the identification, measurement, and prioritization of drivers and responses to technology implementation.

TECHNICAL APPROACH

Concept of Enterprise Harmony

Based on its experiences with total quality management, concurrent engineering, organizational performance enhancement, and both successful and failed technology transition endeavors, the project team formed the working hypothesis that successful technology transition is a change process that must involve the entire enterprise. This hypothesis asserts that all dimensions of the enterprise—its people, technology, and business (Figure 1)—must achieve harmony with the new technology, if it is to be successfully assimilated. As seen in some of the previously cited work, more complex views of an enterprise can be developed; however, the view in Figure 1 is adequate to derive the consequences of the working hypothesis.

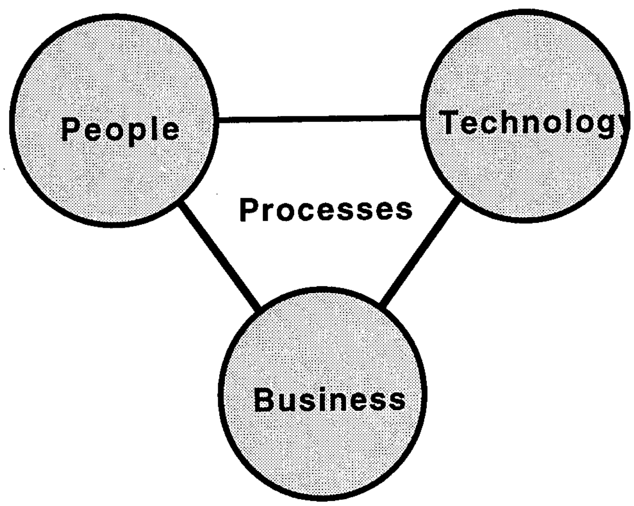

Figure 1
Components of an Enterprise

Consequences of Working Hypothesis

An immediate consequence of the working hypothesis is the categorization of critical success factors into six areas: one for each of the three enterprise dimensions and one for each of the three interaction areas (i.e., people-technology, technology-business, and business-people) between these dimensions. These factors related strongly to barriers of cooperation and communication, which are found at interfaces between enterprise components and between subsystems within these components.

The second consequence is that the attainment of enterprise harmony, which will be upset by the introduction of a new technology, needs to involve a methodology to identify, understand, and mitigate the major barriers to harmony. Armed with this model and its experience, the project team put in place the following strategic elements of a technology implementation methodology.

Strategic Elements

Critical Factors (Objective 1)

A preliminary set of critical factors, cast as barriers to technology implementation, was developed during brainstorming sessions among project team members. These barriers are included in Appendix A. A subgroup of the team was then charged to validate the completeness of the initial set of factors with reference to case studies found in the literature and in the team members' experiences.

Readiness Assessment

Another subgroup of the team was tasked to develop a measurement methodology so that an organization could assess its readiness for technology implementation against the critical success factors just described.

Selection of a Measurement Methodology. A number of recent assessment methodologies exist in areas closely related to the present task of technology transition. For example, the Malcolm Baldrige National Quality Award Criteria; the Software Engineering Institute's Software Capability Maturity Model; Kaplan's Balanced Scorecard; several assessment models for concurrent engineering, including the ones from Mentor Graphics; the CALS/CE Industry Steering Group on Electronics; and the project team's own Concurrent Engineering Research Center are all assessment methodologies. Majchrzak's HITOP program also contains an assessment methodology, about which the project team has at present only sketchy information. Many of these methods involve fairly qualitative determinations of readiness but limited quantitative data. The qualitative assessments yield insights about remedial strategies, whereas the quantitative data (sometimes as simple as "yes," "no," or "somewhat") permit correlation and prediction of success.

The present measurement methodology was selected to achieve a middle ground. Instead of presenting the organization with a set of questions having "yes/no" answers, or answers on a scale from "strongly agree" to "strongly disagree," the team has developed for each critical factor descriptions of different situations that represent different readiness levels of the organization. Persons working with these descriptions identify the situation that most closely corresponds with the present state of the organization. Not only does this methodology produce a quantitative rating (the readiness weight), but it also defines appropriate remedial strategies for increasing readiness, since these strategies are evident from the differences between the situation descriptions. The situation narratives are called "Performance-Based Indicators", which are similar to "Behavior-Anchored Responses" in the field of behavioral psychology.

Performance-Based Indicators for Technology Transition. As an example of how the measurement methodology works, consider the critical factor of the value that the new technology will bring the customers of the business. This factor ("Added Value to the Customer") falls in the "Technology-Business" category and has the following measurements.

ADDED VALUE TO CUSTOMER

Level 1 Nearly all customers are content with the existing technology. The added value to customers from the new technology is mainly a latent value that customers will learn to appreciate.

Level 2 The added value of the technology is apparent to the customers, but many customers are not sure if this value is worth the price and learning effort associated with the new technology.

Level 3 The added value to customers is apparent, and many customers believe this value is worth the price and effort associated with the new technology.

If all other factors are equal, a Level 1 rating anticipates that the new technology would have little or no success; a Level 2, low to moderate success; and a Level 3, moderate to high success. Participants are encouraged to place plus and minus signs next to the levels in order to differentiate the degree to which the indicated situation corresponds with actual conditions in their organization. A "+" indicates a condition in which the readiness assessment was somewhat greater than the level selected but less than the next level. A "-" indicates a condition in which the level selected was not entirely satisfied but the condition was better than the next lower level.

To form the readiness measure for a category, the weighting scheme (1-9) shown in Table 1 should be adopted. If the category does not apply, it should be neglected.

Table 1. Weighting Scheme for Readiness Levels

Level	Weight
1 -	1
1	2
1+	3
2-	4
2	5
2+	6
3-	7
3	8
3+	9

The set of performance-based indicators for each critical factor is shown in Appendix B. The critical factor appears as a capitalized heading; the performance-based indicators are the "level" descriptions under the heading.

Implementation. The readiness assessment can be administered in several ways: as a questionnaire to be completed in private by individuals in the organization; as a template for one-on-one interviews with individuals in the organization: and as a guide for brainstorming with groups of individuals from different parts of the organization. A combination of all three implementation approaches should be used. The questionnaire can achieve broad coverage, although many individuals dislike questionnaires; the individual interview can uncover "deep" knowledge that would not be discovered in a group session or from the answers to a questionnaire; and the group session (conducted according to the nominal group technique) is an efficient information-gathering medium that also leads to creative recommendations and priorities for actions. If possible, one might take advantage of recent research results, which show that persons are more honest with questionnaires administered as computer programs (Sproull & Kressler, 1991).

The readiness assessment results can be plotted in a bar chart or radar (Kiviat) plot to make visible the organization's strengths and weaknesses in technology transition.

Road Map (Objective 2)

Concept. The road map defines a set of planning and implementation steps that organizations should follow in order to achieve the successful assimilation of new technology. The objective of the road map is to promote harmony among the elements of an enterprise: its people, its technology, and its business strategies, processes, and administrative systems. The idea is that, to attain harmony (success) with a new technology, an organization will have to identify and resolve the factors operating to restrain the new technology from being adopted. Conversely, the organization will need to identify and augment those factors operating to embrace the new technology. Since these factors originate from all the different components of an enterprise, they must be dealt with holistically. In this view, the road map defines a change-management process.

The activities associated with the road map may be aggregated into several main stages.

- Stage 1 Develop a business case for new technology and select those technologies that best fit this business case.
- Stage 2 Determine the readiness of the organization and its people to deal successfully with the characteristics of the candidate technology.
- Stage 3 Develop and implement strategies to improve the readiness and understanding of the organization *while introducing the new technology.*
- Stage 4 Monitor, using performance-based metrics, the results achieved with the new technology and implement remedial strategies as required.

Detailed milestones and the map connecting these milestones are shown in Table 2 and in Figure 2, respectively.

Design Intent. The road map has been patterned after the Shewart-Deming "Plan-Do-Check-Act" cycle of continuous improvement (Deming, 1986) and an amalgamation of other change-management strategies. Milestones 1-6 in the road map constitute the planning activity; Milestone 7, the "doing" (implementing) of the plan; and Milestones 8 and 9, respectively, the “checking” for (monitoring) and “acting” on (remedying) deficiencies in the plan and its implementation. This four-phase improvement cycle is widely understood but less frequently practiced by organizations because of a lack of vision and strategic planning skills, a lack of understanding of important metrics, and a lack of both readiness for change and a plan to deal with change. In step-by-step fashion, the road map helps an organization overcome these issues with respect to new technology.

Table 2. Milestones in the Road Map for Successful Technology Assimilation

Milestone Number	*Description*
1	Business case and impact metrics for new technology defined
2	Technology requirements to support business case identified
3	Detailed technology concept(s) selected
4	Readiness categories important to success of new technology determined
5	Organization's readiness assessed and improvement potential estimated
6	Technology transition plan developed based on readiness priorities and uncertainty reduction; readiness priorities for success computed (product of readiness importance and improvement potential)
7	Transition plan implemented in prioritized stages following change-management strategies
8	Implementation progress measured against readiness/uncertainty improvements; technology impact measured against business case metrics
9	Remedial actions introduced as necessary

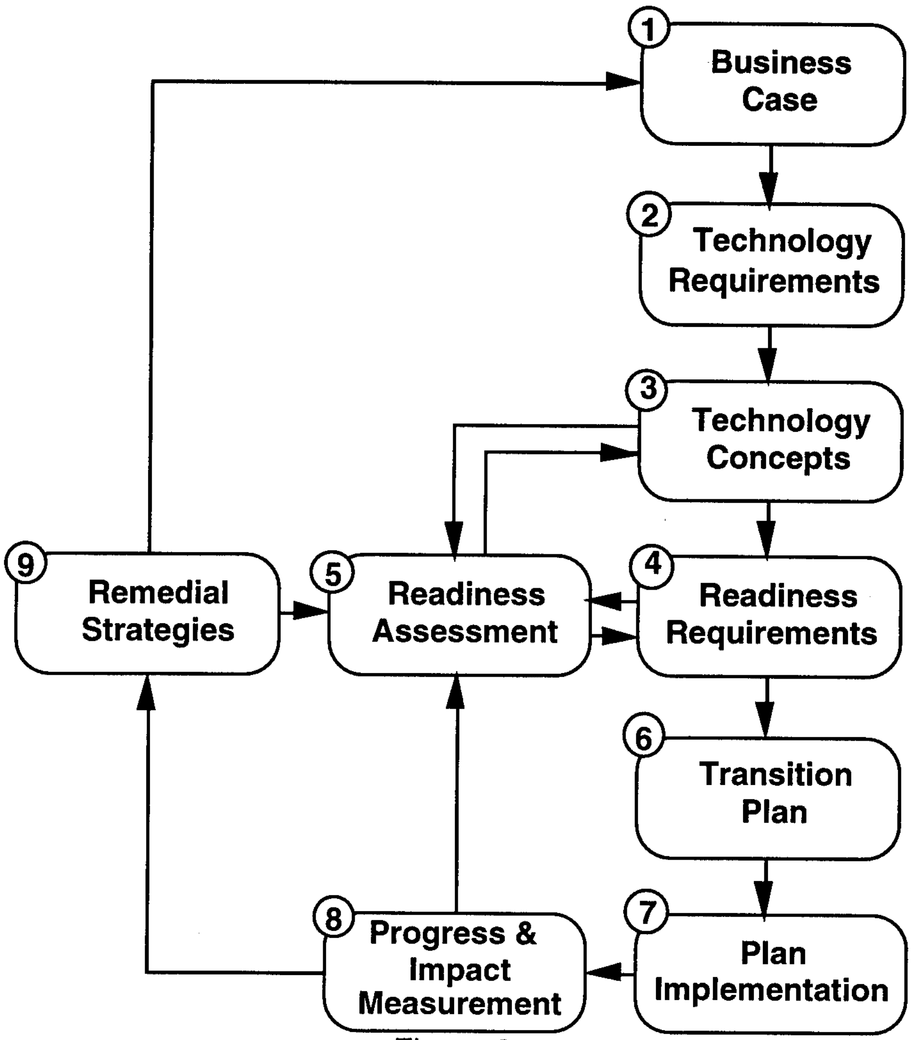

Figure 2
A Road Map for Successful Technology Assimilation

Other change-management steps embedded in the road map have been most heavily influenced by the change strategy developed by the Center for Entrepreneurial Studies and Development (CESD) and are shown here in Table 3.

These steps include developing an awareness and understanding of the context and rationale for the change as well as creating a vision of a desired future state that the change will help to realize. Anticipated benefits for all perspectives of the organization are derived, and effectiveness measurements for the new technology are devised in terms of organizational goals. These features comprise the "business case." Often at this stage, emotional meaning to the change is imparted by a threatening or disruptive event, which might originate from the external environment (such as a precipitous decline in market share to a competitor or the catastrophic failure of a product with loss of life) or from an internal executive decree or action (the "initial rebelling act"), which conveys a strong message from the top that the organization is going to change.

Table 3. An Effective Change Management Strategy (CESD)

Vision Statement of where the organization is going and what it values.
Initial Rebelling Act Some highly visible leadership action that sends the message that current practices are no longer acceptable.
Building a Believer Network Creation of a core group of individuals who support the vision and are willing to put themselves at risk to achieve the vision.
Value-Shaping Events Demonstrations to everyone that improvement is possible, even in activities that have long resisted change.
Spreading the Success Use of initial successes to teach and motivate others to work toward the vision.
Moments of Truth Meeting challenges to the vision and value shaping activities.
Sustaining the Improvement Building ownership and ability to fulfill the vision after the visionary has gone.

In response, or sometimes as the initiating factor, a "believer" network headed by a champion emerges, forms as a team, and is granted (or assumes) the charter for planning, implementing, and managing the change process. Its first function is to co-opt enough multi-disciplinary members to be able to understand the capabilities and capacities of the organization to deal with the proposed change; in the process, the key organizational parameters and sources of resistance to change must be analyzed. These activities comprise the "readiness assessment." Given its systemic nature, the readiness assessment is used to shape the implementation strategy developed next by the working team of believers. Quick successes ("value-shaping events" measured in terms of organizational impact) are sought to build confidence and gain more believers before widespread implementation ("institutionalization") is attempted. Experienced hands will also anticipate, and plan responsive strategies for, premature upsets to the change implementation. Finally, to assure success, the believer network must identify and train capable replacements to sustain the change and lead the next round of organizational improvements.

Although sequential in appearance, the road map should not be construed to be a "waterfall" process, whereby the persons responsible for achieving one milestone hand off their responsibility to another group charged with attaining the next milestone. Rather, to ensure success, the road map should be pursued by a core technology implementation team that sees the process through to completion. In large organizations it is preferable that the technology implementation team report to an organizational improvement steering committee that contains senior executives. The attainment of the milestones should involve the collaborative efforts of a cross-section of the organization's best and most knowledgeable people, including the future users and maintainers of the technology. In this way, given also the system's perspective of the readiness assessment, the technology implementation can be integrated with the organization's social, technical, and business elements.

Business Case. The road map starts with the business case, since the business case defines the reason for the organization's existence. The business case, as developed and articulated by the organization's leadership with participation from other contributors in the organization, should serve several key functions.

- It establishes the context for the new technology and related changes in terms of the organization's external and internal environments.

- It provides a vision for a future desired state and the benefits that the organization and its people, customers, and shareholders will derive from the technology innovation.

- It considers the fit of the new technology with the organization's mission, objectives, strategies, and goals.

- It defines the measurements by which the success of the new technology can be judged.

Kaplan's "Balanced Scorecard," augmented by an explicit category for human development, is an excellent tool to use in developing a business case (Kaplan & Norton, 1993). An example of the modified "Balanced Scorecard" is shown in Figure 3.

Readiness. Next. the organization's readiness to deal with candidate technologies that satisfy the business case is assessed. The readiness assessment described previously evaluates the fit of the technology candidates with the people, culture, policies, capabilities, behavior, processes, resources, and technological infrastructure of the organization. The readiness assessment tool provides both remedial strategies and priorities of their importance to the organization's success with the new technology.

Concept Selection. Technology alternatives, if they exist, need to be weighed carefully against the organization's business case and readiness. A simple decision matrix, showing the alternatives against a common set of readiness and business case criteria, is used to facilitate an objective selection. A major caveat, discovered by Liker et al. (1992) and by others, is that simple pay-back analyses can undervalue the advantages of a technology. Indeed, this observation motivates the use of the balanced scorecard.

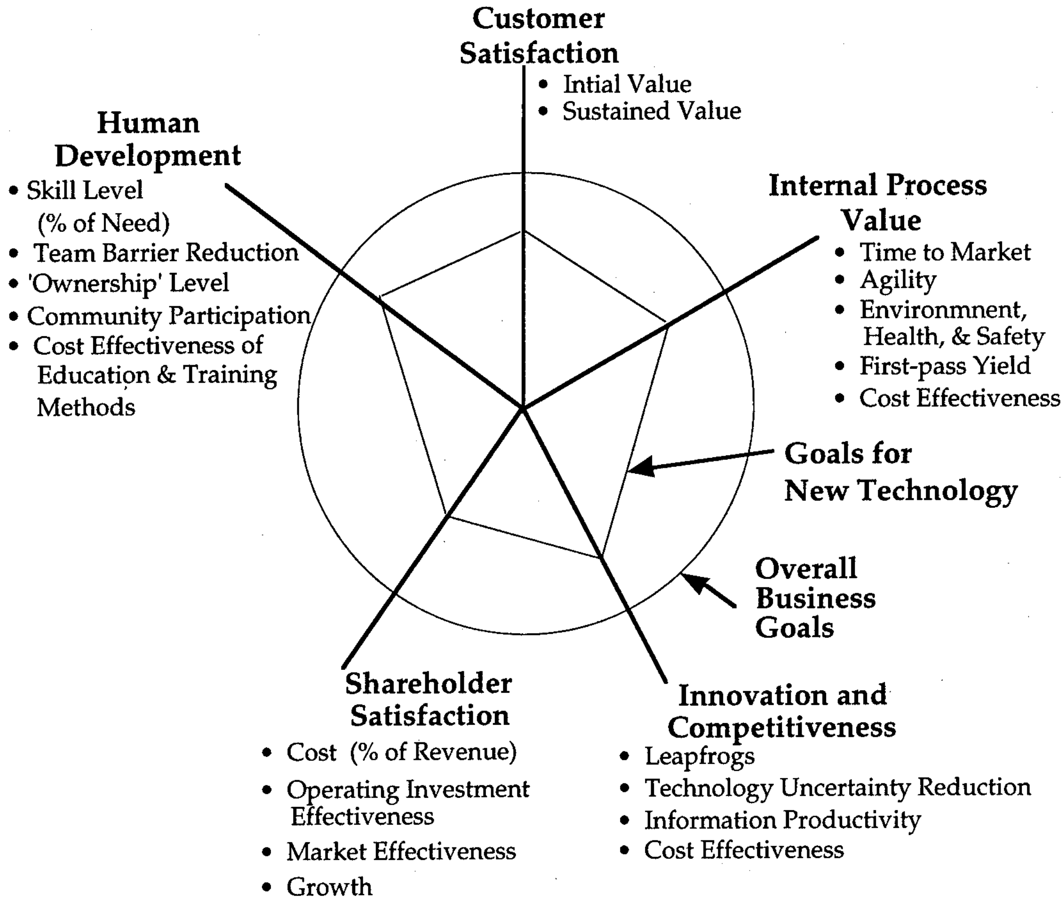

Figure 3
The Modified "Balanced Scorecard"

Implementation. The milestones in the road map need to be under the oversight of a Steering Committee, which is comprised of a core team of members who believe in the organization and in its need for change. Believers should be well respected by others in the organization, willing to take risks, come from the different perspectives of the organization, and represent the organization's corporate knowledge about its customers, operations, products, services, and people. The Steering Committee should contain senior management, or at least be a bridge to them.

The Steering Committee is chartered to translate and uphold the corporate vision and values throughout the technology implementation process; to understand and communicate the business case, technology opportunities, and expected benefits from the new technology; to conduct the organization's readiness assessment and understand its apprehensions; to commission a technology innovation team of users and support personnel to assist in the selection, planning, and implementation of best technology options; to identify and request resources needed for the technology implementation; to commission "just-in-time" training for human resource development and required skills; to champion new incentive approaches commensurate with new responsibilities and skill requirements; to assist the technology innovation team in designing and implementing validation pilot projects followed by an organization-wide, phase-in strategy for the new technology; to monitor progress and problems; and to develop remedial actions as required. In short, the responsibility of the Steering Committee is to navigate the road map.

Out of the business case and readiness assessment comes a technology transition and transformation plan that is tailored to the specific needs and characteristics of the organization as well as to the specific features of the selected new technology candidate. Risk elements of the plan are identified and used to develop a quantified uncertainty reduction trajectory, against which progress is tracked. In effect, each issue of low readiness represents an uncertainty in the success of the technology transition, so the uncertainty reduction trajectory defines progress in resolving barriers to the transition. This concept is shown schematically in Figure 4.[1]

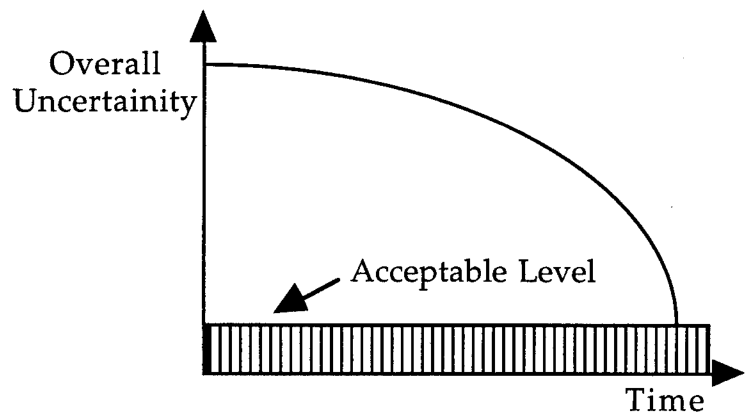

Figure 4
Implementation Progress Measured by Uncertainty Reduction Plan

A significant implementation issue faced by the Steering Committee and its Technology Innovation Team is the design and conduct of appropriate pilot tests or trials of the new technology. These trials are needed to validate the anticipated benefits of the new technology and to increase the network of believers in the new technology, to identify problems, and to help the organization design a broad, phased implementation approach. A complex technology that lacks the characteristic of "trailability" (in the words of Tornatzky and Fleischer, 1990) or "phasing" (in the terms of the present readiness assessment) contains a built-in barrier to its success. Similarly, the absence of a plan for incrementally introducing a new technology detracts from the readiness of the organization.

As a guide, several pilot project design criteria derived from the authors' experiences are given in Table 4.

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[1] A more detailed description of uncertainty-reduction methodology, together with a general methodology for performance measurement, is planned to be prepared and submitted later as an appendix to this report.

Mechanics. The detailed mechanics of the road map's implementation are provided by QFD (Hauser & Clausing, 1988). This methodology has proven to be an effective tool for multi-functional teams to use collaboratively in establishing priorities and assigning and propagating requirements to an organization to fulfill. A QFD matrix helps an organization translate a set of weighted requirements into a set of prioritized solutions. In the present case, the road map is constructed from several linked QFD matrices, which propagate business-case requirements to technology solutions to organizational readiness for these solutions to a plan to enhance readiness for the technology to strategies for improving the plan. The completion of a QFD matrix element by the technology innovation team constitutes the attainment of a milestone in the road map. The linkage between matrices (milestones) occurs by transposing the

Table 4. Pilot Project Selection and Design Considerations

- The project should involve the application of the technology to a *real* project whose outcome will be recognized as meaningful to the organization.
- The project should have an effective champion and the attention of senior management.
- The project should have an associated risk of failure, whose consequences to the organization will be observable but contained.
- The outcome should be measurable in terms of both the effectiveness of the technology implementation process and the impact of the technology itself.
- Success will require cooperation among the organizational elements and people who are affected by the new technology, and all can be represented on a technology transition team.
- Most readiness issues should be resolvable as part of the implementation plan by "just-in-time" training and other "real-time" interventions within the scope of the responsibility, authority, and resources of the transition team and its senior management overseers.
- The project design should represent a valid implementation model that can be scaled up to cover the organization, if the pilot succeeds.
- The project plan should include specific strategies to counter anticipated "moments of truth," which may pose severe threats to the continuation of the project before its planned completion. Such threats can come from new short-term budget priorities; disenchantment because of difficult working conditions with a lack of resources, rewards, or incentives; fair-weather believers or withdrawal of a key person's support; sabotage; or negative results from poorly conceived or hastily obtained measurements, to name a few.

solutions (columns) from one matrix into the requirements (rows) of the following matrix. Only the highest priority items from one matrix are passed on to the next, so the procedure creates an efficient implementation plan for the organization. The use of the QFD tool to construct a road map is illustrated below in the results section.

Improvement. Finally, specific remedial strategies, identified at the time the uncertainty reduction plan was developed, should be implemented when progress falls behind the planned trajectory. Some generic improvement strategies are presented in Table 5.

Table 5. Generic Improvement Strategies

- Revalidate the vision, objectives, readiness targets, needed resources and skills, and other underlying assumptions.
- Analyze lessons learned and act on them.
- Enhance incentives and ownership.
- Revisit the organization's value chain (make-buy decisions).
- Bolster human resource development and skills via creative training using discovery-learning and simulation.
- Create win-win partnerships with immediate management and other organizational entities to assure that everybody has a stake in the success of the implementation.

Adoption of Road Map (Objective 3)

Strategy. The plan for how to gain an organization's acceptance and confidence in using the road map for assimilating a new technology needs also to define a change process. In this case, the approach is to apply the road map as the object of itself, that is, to make sure that the milestones in the road map and related change strategy are followed during a program to introduce the road map to an organization.

For most organizations the road map will be a new way of doing business. To be adopted into routine use, the road map will have to overcome several of the same resistance factors that it seeks to help mitigate for the introduction of new technology. For example, the road map should fit with an organization's desire and strategies (business case) to improve its technology innovation processes; the rationale and features of the road map should be understood by both senior management and expected users; senior management should be committed to the road map concept and have clearly communicated this commitment and their expectations to the organization; a champion and cooperating believer network should be behind the road map; the organization should understand how to administer the readiness assessment and not be threatened by it; the road map should provide evident benefit to the organization and carry an assurance of success; and the application of the road map should be easy and relatively quick, so as not to interfere significantly with other priorities.

In the context of the strategy for successful major organizational change shown in Table 3, the adoption plan for the road map would seem most of all to require the building of senior management commitment and a believer network through "value-shaping" events. A significant value-shaping event will be the understanding, gained through a discovery-learning experience, that the road map offers a better approach to technology assimilation than past approaches. As illustrated in Table 6, the road map itself can be used to motivate this understanding.

The discovery-learning process creates a powerful retention of ideas and knowledge. It involves the phases shown in Table 6, which also presents suggested supporting roles of the road map in this learning process.

The reader will observe that the "concept" in this discovery-learning process is the road map itself. This learning process is, in fact, the way in which to gain the adoption of the road map methodology by Air Logistics Centers and other Department of Defense agencies. By extending the "concept" to include both the road map and a real candidate technology for implementation, an organization can follow the same learning and implementation path and not perceive the road map to be "something extra." That is, the planning and implementation of the candidate new technology is used as the "real-time" learning experience for the road map. Prior to the execution of pilot projects, initial discovery-learning strategies particular to the technology may include, for example, physical demonstrations of performance capabilities and features, and appropriate training and practice devices such as testbeds and self-paced, computer-based instruction.

Additional components of the change management strategy outlined in Table 3 can be brought to bear on the road map adoption process as required by the organization.

Table 6. Role of Road Map in Discovery Learning

Learning phase	*Description*	*Role of road map*
Context setting	developing an awareness or need for the concept	business case for importance of new technology to the business: a) need and benefit to customer satisfaction, internal processes, competitiveness, human development, and financial performance; b) benefits to individuals
Emotional acceptance	personally accepting the need for the concept and becoming willing to explore the ideas being presented	readiness assessment: a) revelation at seeing the array of readiness factors and close identity with them from associations with past failures; b) dismay of discovering the often low state of readiness of the organization, the individual's unit, and the individual with respect to the new technology
Demonstration	showing, through self-discovery, that the concept works	case studies: a) use of the road map to analyze technology transition experiences in other organizations motivates an appreciation for the new technology concept and implementation approach and shows individuals that their situation is not different from that of others; b) use of the road map to analyze the reasons for past successes and failures of technology transition in the present organization creates credibility and identity with the organization

Table 6. Role of Road Map in Discovery Learning (Cont'd)

Learning phase	*Description*	*Role of road map*
Practice	applying the concept by one's self	group practice: a) the readiness assessment and other procedures in the road map are most effectively executed by a team, having basic teaming skills, from a cross-section of the organization; untrained teams can begin to practice these skills on their own; b) after a day of effective training the road map planning tools are pencil-and-paper-oriented and readily facilitated by a group member during team meetings; c) the road map procedures are amenable to different training and use strategies; e.g., a computer-based description can be shared in electronically-supported meetings among collocated team members or conferences among distant team members
Memory anchor	developing a way to remember the concept	demonstration strategy: powerful memory anchors can be created using a particular case study or story developed in connection with the road map, making the technology's purpose easy to understand
Action	developing a follow-up plan of attack based on the new knowledge	implementation plan: the later stages of the road map provide for planning and implementation steps to improve the organization's readiness to accept new technology

RESULTS

Critical Factors

Content Validity

The soundness of the road map depends substantially on whether an organization can be presented with a comprehensive list of readiness factors that are known to be important in technology implementation. The results of the search for readiness factors in relevant case studies found in the literature or known to the project team are listed in Appendix C. Fifteen references, some involving multiple technology implementation cases, were investigated for the relevance of the 39 readiness factors found in Appendices A and B. In the Table presented in Appendix C, an "X" indicates that a particular readiness factor was identifiably involved in the case; a blank indicates that the association of this readiness factor in the case could not be determined from the information given or known.

As seen in Appendix C, all case studies involved multiple readiness factors, but in different mixes. Each readiness factor appears in at least one case study, or (by design) it would not have been kept on the list of relevant factors; conversely, the discovery of a readiness factor not on the list caused the factor to be added to the list.

Priorities

Unfortunately, attempts to provide further analysis of the case study results in order to identify and prioritize a small set of critical readiness factors have proven to be fruitless. The degree of harmony between an organization and a new technology was found to depend on the specific characteristics of the technology and on the specific characteristics of the organization, including the complexity of its processes. There are, thus, too many combinations of variables involved to allow one to separate effects, measure individual impacts, then synthesize generalizations. For example, the response of an organization to a new technology depends, in part, on whether the technology automates "favorite" or "objectionable" human processes, or augments (as opposed to automates) human capabilities, or manages data or contributes to managing relationships between humans, or reinforces or breeches psychological contracts among people and between people and the organization, to cite just a few confounding factors. In the most controlled and best documented case study (Erkes, 1992) that the project team had access to (and, indeed, were involved with during the actual pilot project), the technology implementation team eventually abandoned trying to assign priorities to the many factors that were involved in making the project successful. This case was also not complicated with the business issues of the organization. Compared with this case, most other relevant cases found in the literature and in experience are much less quantified and documented.

In view of these findings, the project team concluded that each readiness factor should be assigned equal importance in the road map, unless the organization possesses insights that permit distinctions between readiness factors to be quantified. This "equi-partitioning" means, for example, that the presence of an active champion is initially assumed to be as important to the success of the technology implementation as is the availability of adequate resources or the perception that the technology is not a fad.

Within a readiness factor, however, the degree or weight of readiness will depend on the nature of the new technology and its interactions with the social, technical, and business subsystems of the organization. These interactions are defined and quantified in terms of the performance-based indicators given in Appendix B. Priorities for action are thus identified as those areas where the organization has low readiness with respect to the specific issues associated with the new technology.

The next section illustrates the application of the road map and the readiness assessment for two real technology implementation examples.

Road Map Illustration

Introduction to Case Studies

In keeping with its logistics support mission, the Armstrong Laboratory/HRG sponsor and the project team identified and worked with the San Antonio Air Logistics Center (SA-ALC) at Kelly Air Force Base as a potential pilot site for the technology adoption and implementation methodology contained in the road map. Within the scope of the present project, the project team conducted a readiness assessment of the Production Process and Engineering LAPME Section of the SA-ALC's Aircraft Production Division LAP and gathered enough information to be able to construct case studies of two previous technology implementations accompished by LAPME. The LAPME section supports manufacturing and repair facilities and related technology developments. In particular, it oversees the extensive "back shop" and composites manufacturing and repair facilities located in Buildings 337 and 522, respectively. LAPME also supports the SA-ALC's Robotics and Automation Center of Excellence (RACE), which was chartered to be the command-wide focal point for improving process productivity in aircraft remanufacturing by the judicious insertion of robotics and automation technology.

Three visits to SA-ALC were needed by the project team to tour and understand the facilities, to explain the road map methodology to the organization and gain the commitment of its management to proceed, to identify an appropriate technology implementation case study, to interview the technology implementation participants, and to obtain information from headquarters relevant to the SA-ALC's strategic plan. Two technology implementation cases were selected for study, because their project engineers are still in the organization and could identify personal experiences with the readiness factors.

Robotics Paint Cell. A desire to improve the painting of manufactured or repaired aircraft parts, particularly, to improve the work environment of the back shop, led to a project to develop a robotics paint cell. Some key features of the project were that it had the participation of users in its design and implementation, provided measurable benefit (reduced exposure) to users, had a phase-in plan that started with 50% of production load, and was viewed as job-enhancing and not job-threatening to the workforce, which received training and upgraded skill levels. Once the robotics paint cell was in operation, the organization initiated actions to increase pay grades commensurate with the new skills required by the workforce. The robotics paint cell is an example of the balanced scorecard at work, for the cell contributed to the organization's objectives of enabling its people to excel and improving the physical environment where they work, but (as was known early) the cell did not increase productivity. In a less progressive organization, this project would most likely not have been undertaken.

Water-Jet Cutting Cell. Water-jet cutting technology was introduced as a high-technology solution to trimming composite materials in LAPME's manufacturing and repair facility for aircraft parts made from composite materials. The technology appears to have been introduced as "something good to do" by management, and early hand-operated versions of the technology posed drawbacks: Operators were reluctant to use the machine for fear of working in close proximity to the high-pressure jet; operators were splashed in the face during cutting; and the machine could not cut a wide range of part materials and thicknesses. These problems were all corrected with the implementation of a robotics manipulator for the cutter and the addition of abrasives to the cutting stream. A persistent problem with the noise of the high-pressure jet can be readily solved by an anechoic enclosure. Steps to train the workforce to use the CAD system interface to the computer numerical controller are underway. To date, the master production scheduler has not been integrated with the capabilities of the water-jet cutting cell, and there seems to be a shortage of qualified operators who can both program and run the cell; thus, it appears to the workforce that their existing methods (bandsaw and grinding) are satisfactory and more productive than the cell, given the set-up time required to program a new cutting path via the CAD system interface.

Both technology implementations have been guided by effective project engineers, who have also been the enthusiastic, day-to-day champions for the projects. The engineers inherited their project from predecessors but have been with their projects long enough to have put a personal "stamp" on it. The robotics paint cell appears to have had more visibility to the organization than the water-jet cutting cell.

Business Case (Milestone 1)

The business case for the SA-ALC derives from its current strategic plan, which is being evolved to reflect the changing defense environment of the 1990s. The current plan, which is a 5-year implementation master plan that supports the SA-ALC's 30-year plan prepared in 1988, has five major goals.

1. Satisfy Our Customers' Needs
2. Enable Our People to Excel
3. Sustain Technological Superiority
4. Enhance the Excellence of Our Business Practices
5. Operate Quality Installations

These goals have been broken into several subgoals, for which multiple objectives have been identified. In all, there are 18 subgoals and 46 objectives. Note the correspondence between the five goals of the plan and the "balanced scorecard plus one" shown in Figure 3. In the present case, there is a one-for-one mapping to customer satisfaction; the strategies for "enhancing the excellence of our business practices" look to internal process improvements that impact both the organization's immediate customers (the Air Force commands that use the refurbished aircraft) and shareholders (ultimately, the taxpayers); "operating quality installations" addresses human needs for the quality of life in their workplaces and in the communities where they live and play; and "sustaining technological superiority" recognizes the importance of innovation and competitiveness. The terms "business" and "competitiveness" have taken on new meanings to all of the Air Force's Air Logistics Centers in the present lean environment of the defense department and this country's initiatives for national economic security. As an example, Brink and Peisert (1992) have shown how Kaplan and Norton's balanced scorecard can be used by defense agencies to measure and improve their strategic performance.

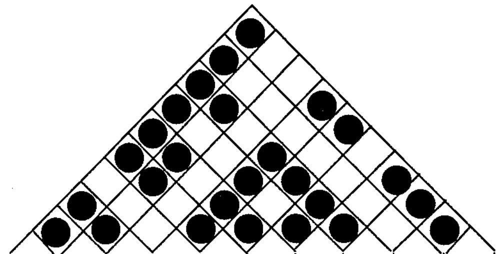
To represent the business case with the aid of QFD methodology, the preceding list of "enterprise drivers" was related to a set of solution characteristics, as shown in Figure 5. Lacking detailed knowledge of the SA-ALC's actual priorities, the project team hypothesized the priorities for the enterprise drivers (goals) and also created a plausible set of *technology-based* enterprise requirements that could fulfill these drivers. For the sake of this example, the project team took some licenses with the actual plan by grouping and distilling some objectives. Although there are many other enterprise requirements that will be needed to respond to the enterprise drivers, the present effort focused on technology. For example, under the goal of "enabling our people to excel" is an SA-ALC response "establish a joint service career development and broadening program," which is extremely important but will probably not involve technology in its implementation.

In Figure 5 the so-called technical importance of each enterprise requirement was derived systematically by determining its impact, in turn, on each of the enterprise drivers. As shown, the strength of the impact is represented by an appropriate symbol, which stands for the numerical weight indicated in the key. Once determined, the technical importance values were renormalized ("scaled") to a 1 to 9 scale, where 9 is high. The roof-shaped matrix above the enterprise requirements evidences relationships that exist between the requirements. For example, the reuse of parts, processes, and data will reinforce the availability of just-in-time parts and information.[2]

This completes the business case (Milestone 1 in the road map), which identifies and quantifies the importance of a set of technology-based enterprise requirements needed to support the business plan for assuring the future health of the enterprise. Recall that this is a group activity performed by the knowledgeable Steering Committee described previously. The three enterprise requirements having the highest importance were found to be, in descending order, matched workforce skills,

[2] Information about reinforcements and constraints among the characteristics in the "roof" of the so-called "house of quality" identifies where tradeoffs need to be made or opportunities exist for clustering actions. The preset example will purposely avoid these complications in order to illustrate the road map concept. The additional features associated with the "roof" can be accounted for later.

● ***Strong (9)***
◑ ***Moderate (3)***
○ ***Weak (1)***



Enterprise Drivers / ***Enterprise Requirements***	***Priorities***	Productivity	Max. Reuse Parts,Processes,Data	JIT Parts & Info.	Matched Wkforce Skills	Rapid Prod. Assurance	Mistakeproofing	Min. Changeover Time	Robust P & P Eng.	Green Engineering	Cost-Effective Tech.
Satisfy Customers—C, T, Q	9	●	●	●	●	●	◑	◑	◑		◑
Enable People to Excel	9				●		●				●
Sustain Technology Superiority	7				●						●
Enhance Processes (T, C, I)	7	●	●	●	●		●	●	◑		●
Operate Quality Installation (EHS)	5	◑			◑		●			●	◑
Technical Importance		159	144	144	303	81	216	90	48	45	279
Scaled Importance		5	4	4	9	2	6	3	1	1	8

(Abbreviations: C,T,Q=cost, time, quality; T, C, I=throughput, cost, inventory; ESH=environment, safety, and health; JIT=just in time; P&P=product and process)

Figure 5
Business Case for Road Map Example

cost-effective technology, and mistake proofing. A key feature of QFD methodology is that the importance ratings of all the enterprise requirements derive from the business priorities of the enterprise drivers; these priorities are also propagated to subsequent milestones.

Technology Characteristics (Milestone 2)

The next milestone in the technology implementation road map involves the identification of a high-level set of technology characteristics that can satisfy the enterprise requirements developed at the previous milestone. As shown in Figure 6, to accomplish this task, the enterprise requirements from the preceding chart are deployed to a new matrix.

Suitable technology characteristics are found in one or a combination of two ways: bottom up or top down. Note that one technology characteristic will generally satisfy multiple enterprise requirements. In the bottom-up approach, the Steering Committee answers the following question in turn for each of the enterprise requirements: "What technology characteristic(s) will have a major impact on this enterprise requirement?" In the top-down approach, the Steering Committee brainstorms a set of technology characteristics. Either way, the exercise of determining the strength of the relationships between the technology characteristics and the enterprise requirements provides a "sanity" check on the results, for an empty row indicates that there is an unfulfilled enterprise requirement (for which technology solutions need to be identified), whereas an empty column indicates an extraneous technology characteristic that at face value is not satisfying any of the enterprise requirements. On the other hand, if the supposed extraneous technology characteristic is known to be important, then the Steering Committee should suspect that it has missed an enterprise requirement and should discover what it is.

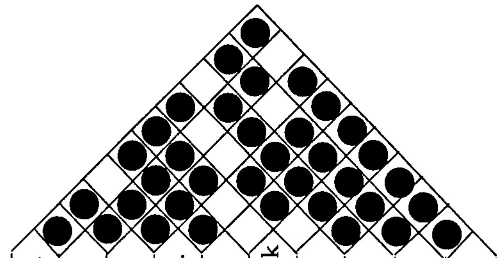
The technology characteristics evidenced in Figure 6 were selected to support an integrated, collaborative working environment with some advanced application tools and process automation. The infrastructure for collaboration consists of a distributed computing network with services for integrating users and their programs and databases; a master model of information related to products, processes, and the capabilities and availability of the resources supporting the processes; standards for representing, exchanging, archiving, and retrieving information; and a corporate memory of best practices, intent, and lessons learned. This kind of environment, when used by multi-disciplinary teams, represents an evolving, successful approach to achieving dramatic improvements in cost, schedule, quality, and flexibility of products and services. In the commercial world the approach is known variously as concurrent engineering, integrated product development, integrated product and process development, simultaneous engineering, or integrated development process; in the Department of Defense, the approach is known by the same or similar names, and the environment is that of the IWSM program.

Besides these features, two other important characteristics were included: multimedia, computer-based training and education for the workforce, and a technology transition plan. The latter will be recognized as self-serving to the justification of the road map.

● ***Strong (9)***

◑ ***Moderate (3)***

○ ***Weak (1)***



Enterprise Requirements / **Technology Characteristics**	Importance	Master Information Model	Standards	Corporate Memory	Multimedia Training & Ed.	Rapid Prototyping	Collab. Computing Network	Solids & Parametric Modeling	Design for X	Process Automation	Technology Transition
Productivity	5	◑	●	●	◑	◑	◑		●	●	◑
Max. Reuse Parts, Proc., Data	4	●	●	●				◑	◑	●	◑
JIT Parts & Information	4	●					●				◑
Matched Workforce Skills	9			●	●					◑	◑
Rapid Product Assurance	2	◑	◑	◑		●	◑	◑	●	◑	◑
Mistakeproofing	6	◑	◑	●	●	●	◑		◑	◑	◑
Min. Changeover Time	3									●	◑
Robust P & P Engineering	1			◑		●	◑	●	●		◑
Green Engineering	1								●	◑	◑
Cost-Effective Technology	6				●	◑	◑			◑	●
Technical Importance		111	105	225	204	114	96	27	111	180	159
Scaled Importance		4	4	9	8	5	4	1	4	7	6

Figure 6
Technology Characteristics for Road Map Example

The second milestone in the road map has been reached. The four technology characteristics of highest importance to the organization are corporate memory, multimedia training and education (for the new technologies), process automation, and the technology transition plan.

Technology Concepts (Milestone 3)

Up to this point the technology characteristics have been kept as general descriptions so as not to influence the creativity of the identification process. Technology alternatives using information about state-of-the-art capabilities and future directions will now be explored. Gathering this knowledge may be the responsibility of technology planners already in the organization; if not, the organization should consider forming such a group or contracting the services of an outside consulting firm.

From among several alternative technology solutions that are compatible with the technology characteristics established at the preceding milestone, the Steering Committee and its resources engage in a group decision process to select a technology concept. In this case the technology concept that best fits the enterprise requirements and has the highest degree of organizational readiness for implementing it is the one selected. (Note, in Figure 7, that overall readiness is given the maximum importance of 9.) The Pugh concept selection methodology, which produces a decision matrix for comparing candidate concepts against a reference concept, provides a quantified rationale for making the selection.

The introduction of readiness requirements for new technology concepts creates the need for a simultaneous solution of the concept selection, since the organization's readiness to implement a new technology is dependent on the nature of the technology. As shown in Figure 7, a first solution can be obtained by neglecting the readiness issues.
Then the readiness assessment can be conducted for each of the candidate technology concepts and the selection results refined. In the present example, the states of readiness discussed later widen the difference between the choices.

The two technology concepts, robotics paint cell and water-jet cutting cell, shown in Figure 7 are possible responses to the Process Automation technology characteristic, which was discovered to have the third highest priority at Milestone 2. For the sake of this illustration, one assumes that the Steering Committee has already selected concepts to deal with the two highest priority issues before tackling Process Automation. Note also that there may be other automation alternatives that have higher benefit to the organization than the robotics paint cell and the water-jet cutting cell, but other alternatives were not investigated as part of the present example. Finally, within each global concept there are usually a number of component concepts whose possible configurations need to be considered in order to arrive at a strong global concept. For example, in the water-jet cutting cell some subordinate concept choices include plain or abrasive-laden water jet, gantry or articulated-arm robot, CAD-driven or teach-pendant interface, simple or flexible fixtures, and individual hearing protection or anechoic enclosure. These considerations are best tackled by technology innovation teams of potential users and supporters, which are commissioned by the Steering Committee.

With the selection of best technology concepts to satisfy the enterprise requirements, the Steering Committee has attained Milestone 3 in the road map.

● *Strong (9)*

◑ *Moderate (3)*

○ *Weak (1)*

Enterprise Requirements \ Technology Component	Importance	•	•	•	Robotics Paint Cell	Water Jet Cutting Cell
Productivity	5				◑	●
Max. Reuse Parts, Proc., Data	4				●	●
JIT Parts & Information	4				◑	◑
Matched Workforce Skills	9				◑	
Rapid Product Assurance	2				◑	○
Mistakeproofing	6				◑	◑
Min. Changeover Time	3				◑	
Robust P & P Engineering	1					
Green Engineering	1				●	
Cost-Effective Technology	6				◑	●
Technical Importance					150	119
Scaled Importance					6	5

Figure 7
Technology Concept Selection for Process Automation without Readiness Criteria

Readiness Requirements (Milestone 4)

Depending on its knowledge of the organization, the Steering Committee may decide at this point to select and prioritize pertinent readiness requirements (factors) listed in Appendix A before conducting the readiness assessment. Otherwise, the Steering Committee can take the factors as given and assume that each factor has equal importance. This introspection, when possible, can simplify the readiness assessment task and sharpen its results.

Readiness Assessment (Milestone 5)

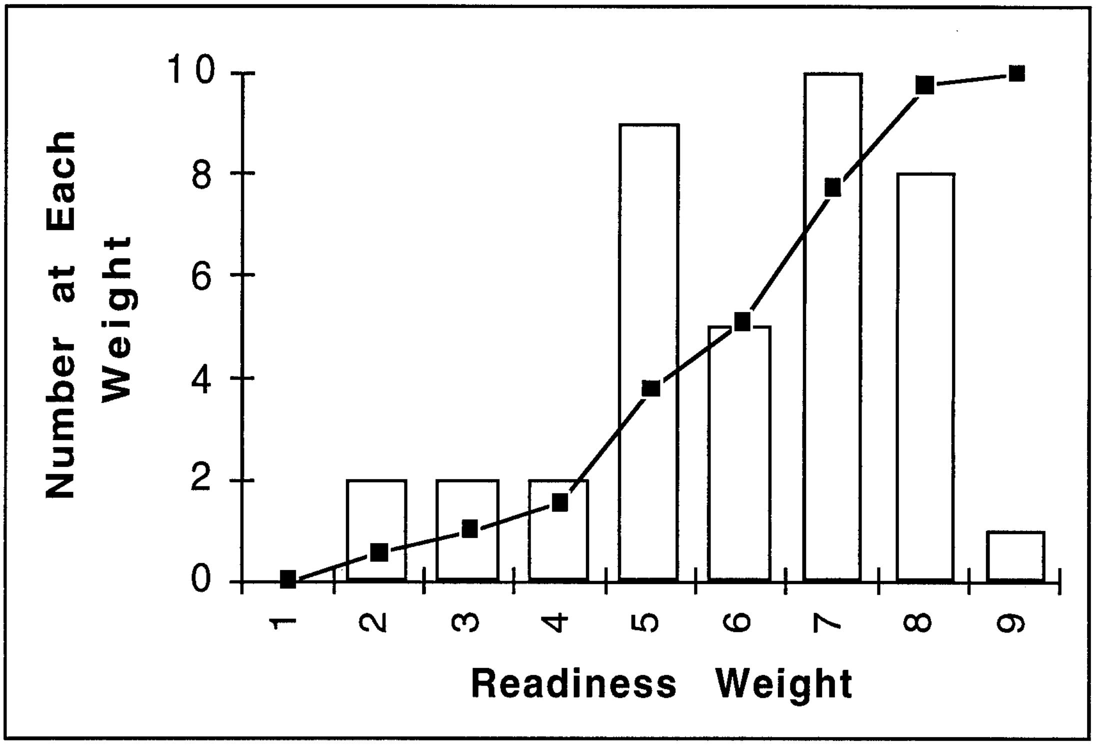
The Steering Committee next administers the readiness assessment by asking cross-sections of the organization to match their status *relative to the chosen technology* with the performance indicators given in Appendix B. In this way, as explained earlier, a readiness level or weight from 1 to 9 (1 low, 9 high) is derived for each readiness factor.

In the present example, the results of the project team's readiness assessment, based on interviews with people in the SA-ALC's LAPME organization, are shown in Figure 8 for the two technologies. This figure compares the individual cumulative distributions of the readiness weights for the two cell technologies. The average readiness weight for the water-jet cutting cell is 4.3; whereas, that for the robotics paint cell is 6.1. The actual weights for each category are presented in Appendix D.

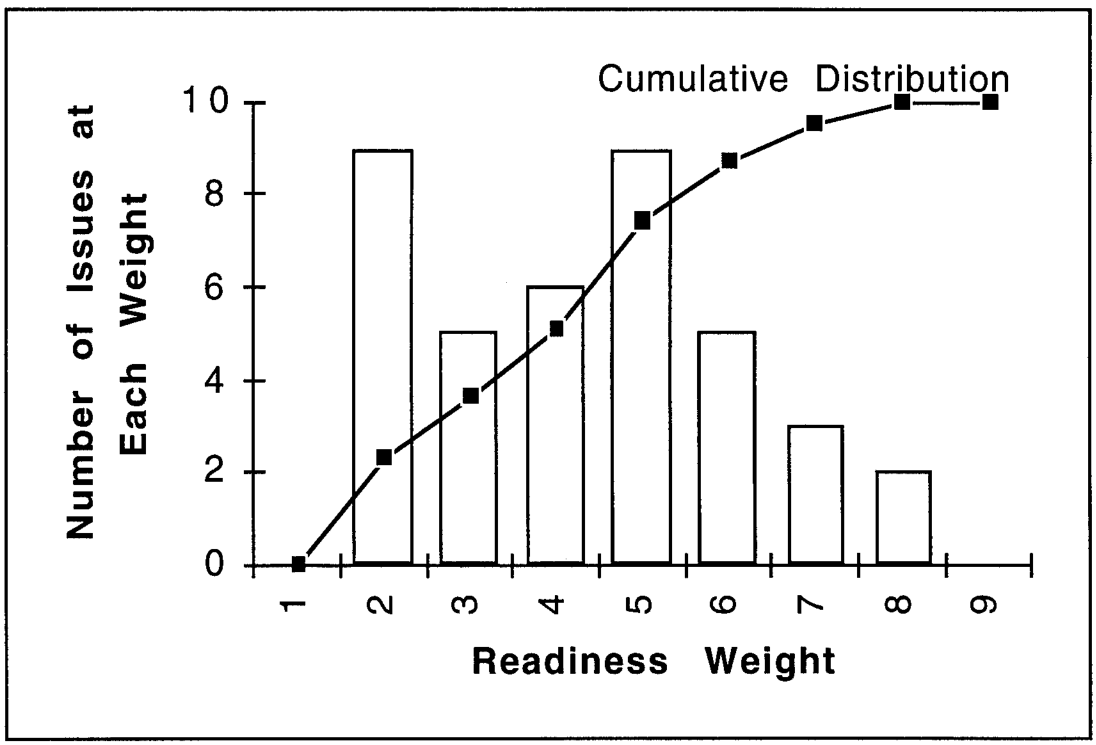
One sees from the results in Figure 8 that there are many more issues of low readiness for the water-jet cutting cell than for the robotics paint cell. In fact, the first 20% of the water-jet cutting readiness factors have the low weight of 2; whereas, this weight applies to only 5% of the robotics paint cell readiness factors; 80% of the robotics paint cell readiness factors have the weight of 7 or higher.

With the readiness assessment provisionally completed (Milestone 5), one can revisit the technology concept evaluations shown earlier in Figure 7. The evaluation of a concept should account for both its technical importance and the organization's readiness for it. One scheme for combining these factors is based on the notion of value, defined as the quotient or difference between the benefit of something and its price or cost. In this case, the Technical Importance of the technology concept can be construed to be the "benefit," and the Readiness Potential, or difference between full readiness (weight of 9) and the current level of readiness (weight of R), can be interpreted as the "cost." Quotients of one or greater signify positive value, the greater the better. Another scheme based on the notion of risk is being developed but will not be described here.

Figure 9 shows the information given in Figure 7 for the technology selection but with the addition of the readiness results and the value computation. Here, the robotics paint cell is seen to have almost twice the "value" of the water-jet cutting cell (2.1 vs. 1.1) to the organization and, therefore, would be predicted to stand a better chance of successful implementation than the water-jet cutting cell. In fact, after multiple-year efforts on each project, the robotics paint cell is presently in full production; whereas, the water-jet cutting cell is usually idle.



a. Robotics Paint Cell



b. Water-Jet Cutting Cell

Figure 8
Cumulative Distributions of Readiness Weights for the Technology Cases

● ***Strong (9)***

◑ ***Moderate (3)***

○ ***Weak (1)***

Enterprise Requirements \ ***Technology Component***	***Importance***	•	•	•	Robotics Paint Cell	Water Jet Cutting Cell
Productivity	5				◑	●
Max. Reuse Parts, Proc., Data	4				●	●
JIT Parts & Information	4				◑	◑
Matched Workforce Skills	9				◑	
Rapid Product Assurance	2				◑	○
Mistakeproofing	6				◑	◑
Min. Changeover Time	3				◑	
Robust P & P Engineering	1					
Green Engineering	1				●	
Cost-Effective Technology	6				◑	●
Technical Importance					150	119
A. Scaled Importance					6	5
B. Readiness Weight R					6.1	4.3
C. Readiness Potential (9-R)					2.9	4.7
D. "Value" (a/c)					2.1	1.1

Figure 9
Technology Concept Selection for Process Automation with Readiness Criteria

Implementation Plan (Milestone 6)

The preceding construction of the road map for the two selected technology implementations was an exercise in plausibility, since the technologies were already in place when the assessments were done. However, both enterprise drivers used in the business case (Milestone 1) and the readiness assessment findings (Milestone 5) are real; they derive from actual data and the recollections of the people who were involved in the implementations. To complete the illustration of the road map, a reasonable implementation plan will next be developed for the water-jet cutting cell.

The implementation plan can be built using again the QFD tool. This time the readiness requirements and their weights, found after administering the assessment in Appendix B to the organization, are matrixed with appropriate remedial actions that need to be undertaken while the new technology is being implemented. Because of the situation narratives used in the readiness assessment tool, the remedial activities are relatively easy to identify following a "bottom up" approach. For example, when it was first introduced, water-jet cutting appeared to be the whim of a manager, who one day saw an article on the technology in a professional magazine and thought the concept portrayed a "hi-tech" image. To counter this perception, the Steering Committee needs to build a proper business case that demonstrates the real benefits and costs of water-jet cutting technology to the organization and its operators. Next, the training of operators to become facile with the CAD system interface needs to be accelerated; perhaps also an easier-to-use CAD package might be investigated. An adequate support staff needs to be trained and must be available to augment the heavily time-shared, single expert that exists today.

Cooperation with other water-jet cutting sites and production scheduling needs to be bolstered. Completion of the implementation enhancements to the water-jet cutting cell needs to be recognized as a key priority by the organization, which should consider executing a formal, win-win development partnership agreement between the technology transition team and its management, and so forth.

Several of these highest importance needs for the implementation plan have been recorded in Figure 10. In each case the readiness importance is equated to the potential for improvement, measured as the difference between 9, the highest readiness weight, and the current readiness weight. This prioritization is a consequence of the "equi-partitioning" assumption that all readiness categories have equal bearing on the success of the technology implementation outcome. Thus, a readiness weight of 2 within a category has a readiness importance (potential) of 7.

As can be seen in Figure 10, the QFD tool helps to establish a priority for each of the implementation strategies as well as to evidence which strategies reinforce one another (indicated by the symbol in the roof). The next step is to develop an implementation plan that pays first attention to the high priority and reinforcing strategies. Guided by relationships in the roof, the clustering of activities around core strategies can streamline the implementation plan. For the present example, or at least the part shown in Figure 10 for the highest readiness priorities, the ordering of the strategies and the number of their interfaces to other strategies are summarized in Table 7.

Table 7. Priorities for Implementation Strategies

Weight	Implementation Strategy	Number of Interfaces
9	Develop & Execute Partnership Agreement	5
7	Establish Performance Metrics	5
5	Form Technology Implementation Team	8
4	Form Steering Committee	6
4	Develop Business Case	2
3	Select Technology Candidates Assess Organization's Readiness	4
3	Provide CAD Training	3
3	Coordinate with Production Scheduling System	3
3	Consult with ALC Technology Network	3
2	Design Pilot Project	6

A sensible initial approach would be to launch the Steering Committee and the Technology Implementation Team at the same time and provide common team training, if needed. This synergistic approach covers 14 interfaces and has a leverage factor, defined as the product of the weight and the number of interfaces, of 64. As part of the combined launch and training program, the teams could also develop and execute a partnership agreement[3] and define the performance metrics by which all agree to be measured. The leverage factor for this strategic cluster increases to 144.

Once the preceding strategies of highest importance are in place, the performing teams should focus on the next most important implementation strategies. Priorities and clustering logic in the present example suggest that the Steering Committee and the Technology Implementation Team work together to develop a business case and

the organization's readiness assessment for new technology candidates that are being evaluated, with the help of an ALC network of technologists, and subjected to a continuous selection process. The leverage factor for this next strategic cluster is 29.

This process is completed until a plan of activities has been created and scheduled for all of the implementation strategies developed with the aid of the QFD approach illustrated in Figure 10.

Monitoring of the implementation plan is accomplished using the performance measurement methodology that will be described in a future appendix.

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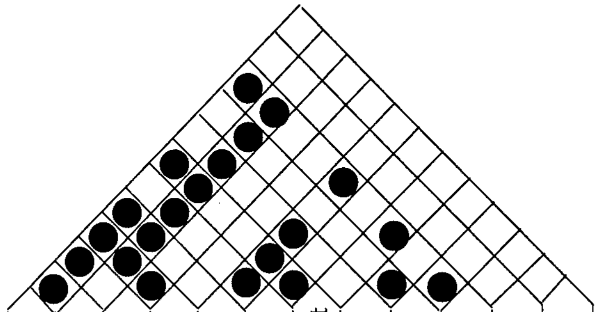
[3] The partnership agreement, between the Technology Implementation Team and its management and the organization, as represented by the Steering Committee, is a win-win agreement that, at the outset, clearly defines for all parties expectations, roles, reponsibilities, authorities, resources, accountability, and consequences. It is a statement of trust.

● **Strong (9)**
◐ **Moderate (3)**
○ **Weak (1)**



Implementation Strategies

Readiness Issues

Readiness Issues	Importance	Steering Committee	Tech. Impl. Team	Business Case	Technology Selection	Pilot Project	CAD Training	Partnership Agreement	Production Interface	ALC Tech. Network	Performance Metrics		
Perceptions	7	◐	◐	●	●	◐		◐	◐	●	◐	●●	●●
Skills	7						●				◐		
Support Staff	7		●					●					
Cross Cooperation	7	●	●			◐		●	●	●	◐		
Priority	7	◐		●	●			●			◐		
Management Systems	7								●		●		
Resources	7	◐		◐				●			◐		
View of Failure	7							●			●		
User Involvement	7		●			●	●	●		◐	◐		
⋮													
Management Commitment	6	●		●				●			●		
⋮													
Technology Risk	1		●		●	●	◐			●	●		
Technical Importance		180	219	201	135	114	129	408	147	156	315		
Scaled Importance		4	5	4	3	2	3	9	3	3	7	●●	●●

Figure 10
Implementation Planning of Priorities for Action

CONCLUSIONS

The concept that enterprise harmony enables successful technology implementation appears to be sound: derived barriers (critical factors) were not refuted by the case studies examined, but more work will be required to establish whether the concept has predictive validity and is repeatable.

It was not possible to develop generic priorities for the barrier factors: Priorities were found to be too dependent on the specifics of the technology and on the specifics of the organization, and there proved to be too many variables and not enough well-documented cases to permit generalization.

However, an organization can discover and prioritize its critical factors by using the readiness assessment tool and process road map that were developed as part of this project.

The road map, constructed using the QFD tool, provides a step-by-step procedure for guiding an organization to enterprise harmony with a new technology. The procedure predicted the outcomes of the two manufacturing case studies examined in detail at the San Antonio Air Logistics Center.

RECOMMENDATIONS

Continued Validation

Information Exchange

It is recommended that a group of national experts in technology transition be convened to critique and improve the readiness assessment and road map methodologies.

Real Pilot Project

The road map needs to be tested from the outset of a real pilot project. The adoption plan for the road map requires first a willing host(s), which is desired to be an ALC that has identified opportunities for new technology. It is recommended that the present project team and its AL/HRGA sponsor develop a management presentation, which establishes a compelling case for the road map methodology. The team would then visit several ALCs and use the presentation as a basis of discussion with senior management in an attempt to gain approval to pilot the road map methodology with their organization.

Process Modeling Adjunct

As an additional development activity, it is recommended that the present methodology be combined with a process modeling capability. The resulting methodology would offer the following comprehensive benefits.

Readiness	likely impact of new technology on people and strategies for increasing the probability of their acceptance of it
Process Model	likely impact of new technology on manufacturing and other value processes of the business
Road Map	implementation plan, strategies, initiatives, and measurements for managing the new technology introduction

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ACRONYMS

ALC	Air Logistics Center
AL/HRG	Armstrong Logistics Research Division
AL/HRGA	Armstrong Laboratory Logistics Research Division Acquisition Logistics Branch
CAD	Computer Aided Design
CALS	Computer Aided Acquisition and Logistics Support
CE	Concurrent Engineering
CERC	Concurrent Engineering Research Center
CESD	Center for Entrepreneurial Studies and Development
HITI	Human Issues in Technology Implementation
HITOP	Highly Integrated Technology Organization and People
IWSM	Integrated Weapon System Management
LAMPE	
LAP	
QFD	Quality Function Deployment
RACE	Robotics and Automation Center of Excellence
SA-ALC	San Antonio Air Logistics Center

APPENDIX A

Critical Factors in Technology Implementation
(Barriers to Enterprise Harmony)

Following are the identified barriers that inhibit successful technology adoption and implementation by an enterprise. These critical factors have been categorized into one of the six categories that derive from the working hypothesis about the importance of enterprise harmony.

People—Technology

- Potential users are unable to see the benefit of the new technology.
- The new technology is hard to use; it is not intuitive or ergonomic.
- The new technology lacks required or expected features.
- The new technology requires revisions of job descriptions or threatens job loss.
- The new technology requires interdepartmental cooperation that does not exist.
- The new technology requires extensive training in new skills and has "low retention."
- The new technology lacks knowledgeable facilitators and a skilled supporting staff.
- People in the organization were not involved with the configuration and selection of the new technology.
- The new technology raises safety concerns.
- The new technology is perceived to be a fad.

Technology—Business

- The new technology lacks a business case; it has unfavorable, unknown, intangible, or hard-to-estimate benefit-to-cost results.
- The business cannot define the added value of the new technology to its customers.
- The business has failed to consider the opportunity costs of the new technology.

Technology—Business (Cont'd)

- The cost of the new technology raises the business "break-even" point in uncertain times.
- Management and technology systems supporting the new technology are lacking.
- The new technology is difficult to monitor and manage.
- The new technology represents a high risk to the business, since it exceeds the organization's relevant experience.
- Time, money, or other resources are not budgeted (or available) for absorbing the new technology.
- The new technology does not fit in with the strategic direction and goals of the business.
- The new technology raises environmental or other social consciousness concerns.

Business—People

- The current organizational responsibility, authority, and accountability structure does not accommodate technology transition.
- Corporate policies for innovation and technology transition do not exist.
- A corporate history of technology-transition failures because of inadequate long-term assignment of personnel (teams) and resources to support technology transition exists.
- The new technology impacts long-standing work practices and union rules.
- The new technology intrudes on traditional relationships (e.g., customers-suppliers, supervisors-contributors).
- The new technology lacks a supportive culture and incentives.

People

- Senior management leadership and commitment to the new technology are lacking.
- A champion does not exist in the organization for the new technology.
- The new technology impacts on existing measurement and reward systems.

People (Cont'd)

- The new technology impacts traditional career paths.
- The new technology encroaches on individual initiative and the ability of individuals to demonstrate excellence.
- The technology transfer team is arrogant or condescending.

Technology

- The new technology is unproved; the organization is dealing with Serial No. 1.
- The new technology has a poor user interface and is not well documented.
- The new technology is not open; it does not support standards and is difficult to integrate with existing systems in the organization.
- The new technology is likely to be eclipsed by new developments in the near future.
- Uncertainty about the availability and support of the new technology and needed options exists.
- The implementation time for the new technology is too long, and it cannot be phased-in to realize incremental benefits.

Business

- The organization lacks knowledge about its readiness for the new technology.
- Ill-defined antecedents and consequences for the new technology exist.
- The organization lacks understanding about the new technology: its concepts, operation, terms, limitations, and issues.
- A plan does not exist for the assimilation and use of the new technology.
- The organization is driven by technology "hype."

APPENDIX B

Readiness Assessment Tool

People—Technology Factors

FEATURES AVAILABLE IN THE TECHNOLOGY

Level 1 Many of the requirements for the technology do not exist in the proposed technology.

Level 2 The proposed technology offers many of the required features, but these features are too expensive.

Level 3 The proposed technology offers virtually all of the features required of it.

PERCEPTIONS OF THE TECHNOLOGY

Level 1 The technology is perceived as being unnecessary, a fad, or a whim of a senior manager.

Level 2 The technology is perceived as being "nice-to-have," but most individuals do not perceive the technology as being necessary.

Level 3 The technology is perceived as being essential to the viability of the organization.

SAFETY FEATURES OF THE TECHNOLOGY

Level 1 There are serious safety concerns associated with the technology. Safety features are largely non-existent and cannot be corrected without major additional work and cost.

Level 2 There are a number of safety concerns with the technology. Most of these concerns are easily corrected. Some safety issues will be hard to resolve.

Level 3 There are no safety concerns associated with the new technology.

ENVIRONMENTAL IMPACT OF THE TECHNOLOGY

Level 1 Serious environmental concerns are associated with the new technology. Environmental problems will be difficult and expensive to correct.

ENVIRONMENTAL IMPACT OF THE TECHNOLOGY (Cont'd)

Level 2 A number of environmental concerns are associated with the new technology. Most of these concerns are easily corrected. Some environmental issues will be hard to resolve.

Level 3 Environmental concerns are not associated with the new technology.

IMPACT ON JOB ASSIGNMENTS

Level 1 The new technology will impact the job assignments of a large number of employees. These job assignment changes will impact job descriptions and, in some cases, the pay grades for employees.

Level 2 The new technology will impact some job assignments. These changes in job assignments will require some job description revisions but no changes in pay grades.

Level 3 The new technology will have almost no impact on job assignments.

TRAINING AND SKILLS REQUIRED BY THE TECHNOLOGY

Level 1 The new technology requires extensive training and upgrading in skills. Many existing employees will struggle to acquire the new skills that are required.

Level 2 The new technology requires extensive training and upgrading in skills. Existing employees should be able to manage the transition to new skills.

Level 3 The new technology requires very little training and skills upgrade.

SUPPORT STAFF REQUIRED BY THE NEW TECHNOLOGY

Level 1 The new technology requires support staff that are not available or not trained to support the technology. Skills will be hard to upgrade.

Level 2 The new technology requires modest levels of staff support that will require training to develop. Skills will not be difficult to upgrade.

Level 3 The new technology requires modest or limited levels of staff support. These skills exist now or will be easy to develop.

COOPERATION REQUIRED BY THE NEW TECHNOLOGY (Cont'd)

Level 1 The new technology requires extensive cooperation among organizational units or people that will be very difficult to achieve.

Level 2 The new technology requires modest levels of cooperation among organization units that should not be hard to achieve.

Level 3 The new technology requires limited levels of cooperation among units that will be easy to achieve.

RESPONSE TO TECHNOLOGY PROBLEMS

Level 1 The organization has a culture that views problems as personal failures. The normal response to problems is to assign blame rather than to learn from the problem.

Level 2 The organization has a past history of assigning blame for problems but has begun to shift to a culture where problems are viewed as a learning-by-doing experience.

Level 3 The organization utilizes problems in a lessons-learned process that continually improves the organization's ability to assimilate new technology.

FACILITATORS TO SUPPORT THE TECHNOLOGY TRANSITION

Level 1 Skilled facilitators in technology transfer who can be called upon to support this project do not exist.

Level 2 Skilled facilitators do exist in the organizations, but their experience is primarily in facilitating teams in manufacturing or other areas.

Level 3 Skilled facilitators are available to support the technology transition effort.

Technology—Business Factors

FIT WITH STRATEGIC DIRECTION AND GOALS OF THE BUSINESS

Level 1 The new technology is pushing the business in a direction that is at odds with its stated strategic direction.

Level 2 The new technology has strategic implications that are not well understood. Some of these strategic implications could counter the stated strategic direction of the business.

FIT WITH STRATEGIC DIRECTION AND GOALS OF THE BUSINESS (Cont'd)

Level 3 The new technology supports and aids the strategic direction of the business.

ABILITY TO ESTIMATE BENEFITS

Level 1 Benefits are mostly qualitative or intangible in nature. Many benefits are debatable with differing views as to whether the proposed benefits are desirable.

Level 2 Some benefits can be quantitatively determined while many others are qualitative in nature. Those benefits that can be measured are generally agreed to by all parts of the organization.

Level 3 Most benefits can be quantitatively measured. A general agreement as to the magnitude of the benefits from the new technology exists.

ADDED VALUE TO CUSTOMER

Level 1 Nearly all customers are content with the existing technology. The added value to customers from the new technology is mainly a latent value which customers will learn to appreciate.

Level 2 The added value of the technology is apparent to the customers, but many customers are not sure if this value is worth the cost and effort associated with the new technology.

Level 3 The added value to customers is apparent, and many customers believe this value is worth the cost and effort associated with the new technology.

FINANCIAL RESOURCES AVAILABLE

Level 1 The technology will be funded from cash flow rather than capital reserves. Cash flow is limited, and unforeseen technology difficulties will severely strain cash resources.

Level 2 The technology will be funded largely from capital reserves. Cash flow will be needed if unforeseen technology difficulties arise.

Level 3 The technology will be completely funded from capital reserves

TIME AND MONEY TO SUPPORT THE NEW TECHNOLOGY

Level 1 — Budget or time allowances for absorbing the new technology into the organization do not exist. Individual organizational units are asked to accommodate the new technology with their own resources. Organizational units are expected to implement the technology without a reduction in other activities.

Level 2 — Some money exists for implementing the new technology into organizational units, but resources only permit the absorption of direct costs. Organizational units are expected to implement the technology without a reduction in other activities.

Level 3 — Sufficient budgets exist for covering the direct and indirect costs of the new technology incurred by organizational units. Organizational units are given extra help during the implementation phase.

TECHNOLOGY MONITORING AND MANAGEMENT

Level 1 — Very little recognition that monitoring and managing of the technology is needed exists, nor does a capability for these functions.

Level 2 — A recognition of the need for monitoring and managing of the technology exists, but limited capability exits for these functions.

Level 3 — Recognition of the need for monitoring and managing of the technology exists, and a capability has been developed for these functions.

MANAGEMENT SYSTEMS SUPPORTING THE NEW TECHNOLOGY

Level 1 — The new technology outstrips the management of the organization. The organization is not able to utilize the technology to its fullest extent. Little recognition that management systems need to be upgraded exists.

Level 2 — The technology is being introduced as management systems are being upgraded. A strong understanding of the need to upgrade management systems exists.

Level 3 — A definite plan to upgrade management systems to support the new technology exists. Many management systems upgrades will be in place prior to the new technology implementation.

SUPPORTING TECHNOLOGIES AND SYSTEMS

Level 1 The technology requires a significant amount of support which does not exist, nor does a plan for providing this support.

Level 2 The technology requires a significant amount of support. A plan is in place for providing this support, but financial resources limit the immediate availability of all the support that is needed.

Level 3 The support required by the technology is significant and is budgeted within the scope of the project, or the system requires very little support.

Business—People Factors

RESPONSIBILITY, AUTHORITY, AND ACCOUNTABILITY FOR THE TECHNOLOGY TRANSITION

Level 1 Responsibilities, authority, or accountabilities for the technology transfer have not been assigned.

Level 2 Responsibilities, authority, and accountabilities have been assigned for the technology transition, but some disagreement on these plans exist.

Level 3 Responsibilities, authority, and accountabilities have been assigned for the technology transition and are clearly accepted by everyone.

ASSIGNMENT OF STAFF AND RESOURCES TO SUPPORT THE TECHNOLOGY TRANSITION

Level 1 The organization has a history of understaffing and underfunding new technology transition projects. These past practices are being followed on this project.

Level 2 The organization has a history of understaffing and underfunding new technology transition projects. The organization has committed to staffing and funding this project properly.

Level 3 The organization has a history of properly staffing and funding new technology transition projects that is being followed on this project.

TECHNOLOGY IMPACT ON RELATIONSHIPS

Level 1 The technology will have a major impact on traditional relationships, both internal and external (customers/suppliers and management structure). These new relationships have not been explored.

TECHNOLOGY IMPACT ON RELATIONSHIPS (Cont'd)

Level 2 The technology will have an important impact on traditional business relationships. These relationships have been examined, and some of these have been well planned.

Level 3 The technology will have a minor impact on most traditional business relationships. Where changes are more significant, these changes are well planned.

SUPPORTIVE CULTURE AND INCENTIVES

Level 1 A high level of anxiety about the new technology exists. Plans to encourage people to adopt the new technology either through support programs or direct incentives do not exist.

Level 2 A high level of anxiety about the new technology exists. Plans to support people in the adoption of the new technology do exist.

Level 3 A conscious effort to reduce the anxiety about the technology from its inception has taken place.

INVOLVEMENT OF USERS IN THE DEVELOPMENT OR SELECTION OF THE TECHNOLOGY

Level 1 The technology has been developed/selected without the involvement of users.

Level 2 The technology development/selection effort has involved users in the technology evaluation process.

Level 3 The technology development/selection effort has involved users from the beginning of the project. Users' input is highly valued.

People Factors

SENIOR MANAGEMENT COMMITMENT

Level 1 Senior management of the organizational unit is not involved in the development planning for the new technology.

Level 2 Senior management is publicly supportive of the new technology but has not allocated the time to the project to be supportive at difficult moments.

Level 3 Senior management has been actively involved with the new technology planning effort from the beginning.

CHAMPION FOR THE TECHNOLOGY

Level 1 A champion for the new technology does not exist.

Level 2 A champion has been designated for the technology, but the champion has not been as effective as he/she could be.

Level 3 A very effective champion exists for the new technology.

IMPACT ON MEASUREMENT AND REWARD SYSTEM

Level 1 The new technology will require a major change in performance measurement and reward systems. These changes are likely to be very disruptive.

IMPACT ON MEASUREMENT AND REWARD SYSTEM (Cont'd)

Level 2 The new technology will require some changes in performance measurement and reward systems. These changes can be managed.

Level 3 The new technology will not have any significant impact on performance measurement and reward systems.

IMPACT ON CAREER PATHS

Level 1 The new technology has a major impact on job sequences and career paths. These changes are likely to be very disruptive.

Level 2 The new technology has some impact on job sequences and career paths. These changes can be managed.

Level 3 The new technology will not have any significant impact on job sequences or career paths.

IMPACT ON INDIVIDUAL INITIATIVE

Level 1 The new technology encroaches on individual initiative and does not allow individuals to demonstrate personal excellence.

Level 2 The new technology limits individual initiative, but outstanding performers can still demonstrate personal excellence.

Level 3 The new technology has no impact on individual initiative.

Technology Factors

TECHNOLOGY RISK

Level 1 The technology is unproved. Significant risks are associated with the technology.

Level 2 Most aspects of the technology have been proved. The new technology has not been used for the intended application.

Level 3 The technology is mostly proved, and other organizations have had favorable experiences with it.

USER INTERFACE

Level 1 The user interface requires considerable technical expertise or detailed training that is well beyond existing capabilities and skills of the intended users.

USER INTERFACE (Cont'd)

Level 2 The user interface requires an extension of knowledge and skill from present levels. Training programs are in place to make the user interface easier to apply.

Level 3 The user interface is very accessible.

INTEGRATION WITH OTHER TECHNOLOGIES/SYSTEMS

Level 1 The new technology does not integrate well with other technologies and systems. As a result, the new technology requires extra effort when integration is required with other systems.

Level 2 The new technology integrates well with most technologies, especially newer technologies. One or two legacy systems in the organization will require some effort to integrate with the new technology. Other integration needs are not significant.

Level 3 The new technology is integrated well with all other technologies where integration is important.

TECHNOLOGY LIFE

Level 1 The new technology is likely to be eclipsed by another technology in the near future.

TECHNOLOGY LIFE (Cont'd)

Level 2 The new technology is in a mature stage of life. Advanced technologies are on the horizon, but these are unlikely to be a viable option until the proposed technology has paid back its investment.

Level 3 The technology is proven state-of-the-art.

ORGANIZATIONAL EXPERIENCE

Level 1 The new technology involves component technologies that are beyond the organization's know-how. A significant risk of recovery exists if the technology fails.

Level 2 The new technology involves some component technologies that are stretches for the organization. A plan to mitigate the risk associated with these unfamiliar technology components is in place.

Level 3 The new technology is completely within the organization's experience.

TECHNOLOGY PHASING

Level 1 The new technology will be introduced with no parallel operation with the existing system.

Level 2 The new technology will be piloted before it becomes fully implemented. Once the pilot test is passed, the new technology will be introduced with no parallel operation.

Level 3 The new technology will be piloted prior to implementation. Once the pilot test is passed, the new technology will be implemented with parallel operation.

IMPLEMENTATION TIME

Level 1 The new technology will require existing operations to be shut down for a significant amount of time. This down time will create serious problems for the organization.

Level 2 The new technology will require existing operations to be shut down for a significant amount of time. A plan to reduce the consequences of the down time is in place.

Level 3 The implementation time will have very little impact on existing operations.

Business Factors

ORGANIZATIONAL READINESS FOR NEW TECHNOLOGY

Level 1 No attempt has been made to assess the readiness of the organization for the new technology, nor does the organization know how to assess readiness.

Level 2 Organizational readiness for the new technology has been evaluated, but very little confidence in the readiness assessment process exists. As a result, limited application of the readiness assessment has existed.

Level 3 A thorough readiness assessment has been conducted and has been used to guide the technology transition effort.

ANTECEDENTS AND CONSEQUENCES FOR THE NEW TECHNOLOGY

Level 1 The reasons for the new technology and its impacts are generally ill-defined.

ANTECEDENTS AND CONSEQUENCES FOR THE NEW TECHNOLOGY (Cont'd)

Level 2 The reasons for the new technology and its impacts are defined in some cases but not all cases.

Level 3 The reasons for the new technology and its impact are clearly defined.

UNDERSTANDING OF NEW TECHNOLOGY CONCEPTS, LIMITATIONS, TERMS, AND ISSUES

Level 1 A broad-based lack of understanding of the concepts, limitations, terms, and issues associated with the new technology exists.

Level 2 A developing understanding of the concepts, limitations, terms, and issues associated with the new technology exists.

Level 3 A clear understanding of the concepts, limitations, terms, and issues associated with the new technology exists.

TECHNOLOGY TRANSITION PLAN

Level 1 — A plan for the assimilation of the technology into the organization is not in place.

Level 2 — Some planning for the assimilation of the technology has taken place, but the plans are focused more on the process side of the technology than on the people side.

Level 3 — A well developed plan for the assimilation of the technology that considers both process and people issues is in place.

TECHNOLOGY INTRODUCTION

Level 1 — The technology has been introduced with considerable public relations that many view as "hype." Many resent the technology because of this hype.

Level 2 — The technology has been implemented with a public relations program accompanied by some awareness sessions designed to introduce the users to the new technology.

Level 3 — The new technology introduction has been focused on training and user knowledge. The system has not been over promoted.

APPENDIX C

Analysis of Critical Factors

Table C-1. Readiness Factors Analysis Summary

Readiness Factor	Reference [1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]
I. People - Technology															
1. Perceptions of the Technology	X			X				X	X	X	X	X	X	X	X
2. Safety Features															X
3. Environmental Impact														X	
4. Impact on Job Assignments	X		X	X	X	X			X	X	X	X	X		
5. Training and Skills Required		X		X	X	X		X	X	X	X	X	X	X	X
6. Support Staff Required		X		X				X	X		X	X	X	X	X
7. Cooperation Required	X		X	X	X		X	X	X	X	X	X	X		X
8. Facilitators To Support	X	X		X				X	X			X	X		X
II. Technology - Business															
9. Fit with strategic direction				X	X			X	X	X		X	X	X	
10. Difficulty Estimating Benefits	X		X	X				X	X	X	X	X	X	X	
11. Added Value to Customers									X	X	X	X	X		
12. Financial Resources Available	X	X		X				X	X		X	X	X		
13. Time to Support		X				X	X	X	X	X	X	X	X		X
14. Monitoring & Management				X			X	X				X	X		
15. Management Systs Support		X			X				X			X	X		X
16. Technology Support Systems				X				X	X			X	X		
III. Business - People															
17. Responsibility for Transition	X			X				X	X			X	X		
18. Assignment of Resources				X				X	X	X	X	X	X		X
19. Impact on Relationships	X		X	X	X		X		X	X	X		X		
20. Supportive Culture	X		X	X	X			X		X	X		X		
21. Orgs. View of Failure														X	X
22. Participatory Design	X		X	X		X	X	X	X	X		X	X	X	X

Table C-1. Concluded

Readiness Factor	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]
	Reference														
IV. People															
23. Sr. Management Commitment	X	X		X			X	X	X	X		X	X	X	X
24. Champions	X	X		X				X	X	X		X	X	X	X
25. Measurement & Reward	X	X	X	X											X
26. Career Paths										X					
27. Handling Resistance	X		X	X		X	X			X					
V. Technology															
28. Technology Risk			X	X			X	X	X			X			
29. Features of Technology					X			X	X		X	X	X		X
30. User Interface		X				X		X			X	X	X		X
31. Integration with Other Systems		X	X		X		X	X	X		X	X	X		
32. Organizational Experience	X	X	X	X			X	X	X	X	X		X		X
33. Technology Phasing	X			X				X	X			X	X		X
VI. Business															
34. Readiness Assessment	X	X		X			X			X					X
35. Understand Effect on Process	X	X	X		X	X	X	X	X	X	X	X	X		
36. Understanding the Technology	X	X		X			X	X	X	X	X	X	X		X
37. Technology Transition Plan				X	X		X	X	X	X	X	X	X		
38. Technology Introduction			X	X	X		X	X		X	X	X	X		
39. Implementation Drivers	X		X							X		X	X	X	

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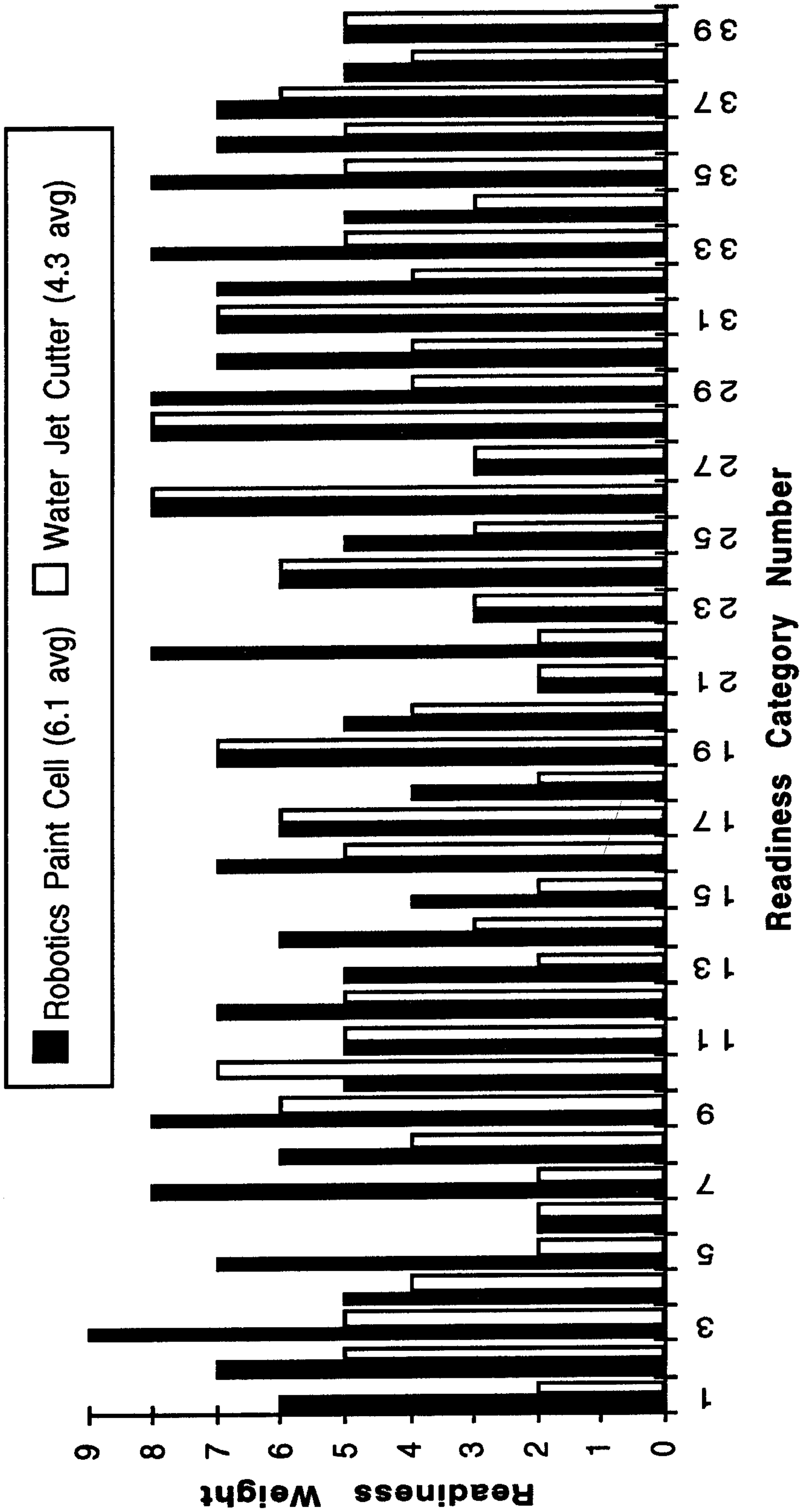
APPENDIX D

Readiness Weights by Factor for Robotics Paint Cell and Water-Jet Cutting Cell Case Studies



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